AD-A122 458 GRAPHICS DISPLAY TEST VOLUME 1 TEST PLAN(U) MARINE 1/1
CORPS TACTICAL SYSTEMS SUPPORT ACTIVITY CAMP PENDLETON
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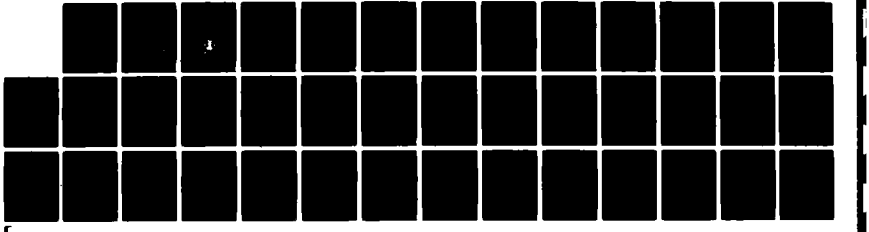

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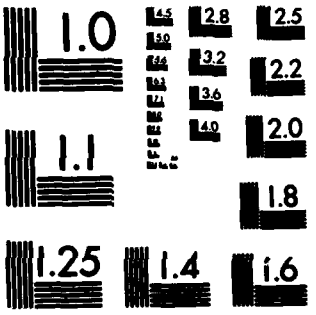

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Display size and the need for a map background have been driving factors in the size and weight of developing automated command and control systems. This test plan describes a test designed to assess the effects of display size and the presence/absence of a military map background as they relate to the functional utility of the graphics display of an envisioned automated command and control system. Test objectives, measures of performance, procedures, and analysis are detailed.

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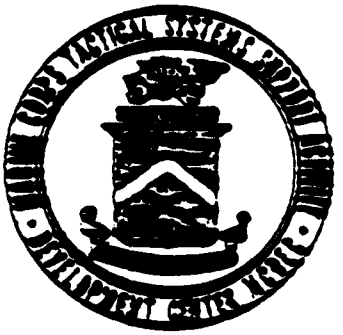
GRAPHICS DISPLAY TEST

VOLUME I

TEST PLAN



MCTSSA

MARINE CORPS BASE
CAMP PENDLETON, CA 92055

1 FEBRUARY 1982

Graphics Display Test

Volume I

Test Plan

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ABSTRACT: Display size and the need for a map background have been driving factors in the size and weight of developing automated command and control systems. This test plan describes a test designed to assess the effects of display size and the presence/absence of a military map background as they relate to the functional utility of the graphics display of an envisioned automated command and control system. Test objectives, measures of performance, procedures, and analysis are detailed.

1 February 1982

Analysis Section
Tactical Systems Development Branch
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Camp Pendleton, California

TABLE OF CONTENTS

SECTION 1
INTRODUCTION

1.1 PURPOSE. The purpose of the Graphics Display Test is to assess the effects of display size and the presence/absence of a map background as they relate to the functional utility of the graphics display for the battalion level Tactical Combat Operations (TCO) supported Combat Operations Center (COC).

1.2 TEST OBJECTIVE

1.2.1 Objective 1. Objective 1 is to evaluate the effectiveness of the various types of graphics displays in providing assistance to the commander.

1.2.2 Objective 2. Objective 2 is to assess the user compatibility of the various types of graphics displays.

1.3 MEASURES OF PERFORMANCE

1.3.1 Objective 1. Two measures of performance (MOP) will be used for Objective 1.

1.3.1.1 MOP 1a. The first MOP for Objective 1 will be the cumulative time required to extract several pieces of tactical information, i.e., information of the sort that is necessary in formulating tactical plans and making tactical decisions, from the graphics display.

1.3.1.2 MOP 1b. The second MOP for Objective 1 will be the total score received by the test participant on the answers given to several tactical questions.

1.3.2 Objective 2. Two MOPs will be used for Objective 2.

1.3.2.1 MOP 2a. The first MOP for Objective 2 will be ordinal judgments expressed by each of the test participants.

1.3.2.2 MOP 2b. The second MOP for Objective 2 will be qualitative assessments by each participant as to the compatibility of the various displays.

1.4 FACTORS. The two principal factors which will be tested are display size and presence/absence of a map background. The test will investigate the interaction effect of the two principal factors.

1.4.1 Display Size. Two levels of display size will be utilized. The large size will be 10-3/4" by 10-3/4" [the approximate size of the Dynamic Situation Display (DSD) as described in the TCO System Description Document (SDD)]. The small size will be approximately 4-1/2" by 4-1/2".

1.4.2 Map Background. Two levels of map background will be utilized. The first level will be the presence of a map background representing the detail of a 1:50,000 paper map behind the tactical symbology on the graphics display. The second level will be a background consisting of only gridlines behind the tactical symbology. In the latter case the test participants will be provided with a paper map.

1.4.3 Display Types. Combinations of the two levels of each of the two principal factors will be utilized so that four display types are tested. The four types are:

a. Large display with map background (Type A)

b. Large display without map background (Type B)

c. Small display with map background (Type C)

b. Small display without map background (Type D)

1.4.4 Other Factors

Other factors such as differences between test participants and scenarios, learning factor and experimentation order will not be explicitly

tested. These factors will be controlled through a relatively large sample (48 test iterations are planned), efforts to minimize variance among participants and scenarios, and deliberate confounding.

Test participants will be 24 officers holding primary ground combat MOSs or other officers with recent tactical training such as Amphibious Warfare School (AWS). Each of these participants will work with two of the four possible display types. The types of displays used by the participants and the order in which they are used will be varied in accordance with recognized experimental design procedures.

1.5 SCENARIO. Two scenarios will be used, both of which will involve a reinforced Marine infantry battalion conducting independent operations within a tactical area of responsibility (TAOR).

SECTION 2

TEST CONCEPT

2.1 APPROACH. The Graphics Display Test is designed to produce a representative combat scenario at the infantry battalion level in order to evaluate the effectiveness of the various graphics displays in providing necessary information to the test participants. The baseline graphics display will be a large display with a map background (Type A). The other display types are alternative to this baseline.

2.2 SCHEDULE. The test will be prepared and conducted in accordance with the following schedule:

a. Test Preparation -- 16 November 1981 to 11 January 1982

b. Pilot Test — 11 to 15 January 1982

c. Test Refinements -- 15 to 30 January 1982.

d. Test Period -- 1 to 11 February 1982.

2.2.1 Test Period. The test period will run the first two weeks of February 1982, in accordance with the following daily schedule:

Day	Event	Number of Participants	Displays Tested AM	PM
Mon 1 Feb	Final GTF Preparation			
Tue 2 Feb	Test	4 participants	AB,BC	CD,BA
Wed 3 Feb	Test	4 participants	CB,DC	AC,BD
Thu 4 Feb	Test	4 participants	CA,AD	DA,DB
Fri 5 Feb	GTF Maintenance			
Mon 8 Feb	GTF Maintenance			
Tue 9 Feb	Test	4 participants	CD,BA	AB,BC
Wed 10 Feb	Test	4 participants	AD,BD	CB,DC
Thu 11 Feb	Test	4 participants	DA,DB	CA,AD

As indicated above, four participants will be utilized on each test day. Each day will be divided into an AM and PM session with two participants involved in each session. Each individual participant will be tested on two of the four possible displays in accordance with the schedule given above, e.g., on the first test day the first participant in the AM session will be tested on display A then on display B, etc.

2.3 PERSONNEL REQUIREMENTS. Personnel requirements for the Graphics Display Test will be provided as follows:

a. Test preparation will be accomplished by Marine Corps and on-site contractor personnel at MCTSSA.

b. Pilot Test participants will be a limited number of officers from MCTSSA who are not involved in test design or preparation.

c. Test participants will be Marine officers provided by LFTC Pac and 1st Marine Division.

d. The Control Simulation Team (CST) will consist of Marine Corps and on-site contractor personnel from MCTSSA.

e. The Data Management Team (DMT) will be Marine Corps officers assigned to the Analysis Section augmented by enlisted personnel from MCTSSA.

2.3.1 Special Qualifications. Test participants will be Marine officers holding a primary ground combat MOS (03, 08, 18) or other officers with recent tactical training such as AWS.

2.4 MATERIAL REQUIREMENTS

2.4.1 Facilities. The test facilities required for this test are the MCTSSA Generalized Test Facility (GTF) located in building 31330 and the MCTSSA computer facility located in building 31337.

2.4.2 Hardware. Hardware for the test will consist of the GTF suite of equipment and the PDP 11/70 system.

2.4.3 Software. Software for the test will consist of the GTF system program, DECNET, IAS and RSX-11M.

2.4.4 Data Base. Data Base Management System-11 (DBMS-11) will be used for the test.

2.5 TRAINING

2.5.1 CST Personnel. Members of the CST will be briefed on test objectives, test duties and test requirements and will participate in test rehearsals and a pilot test prior to the scheduled test period.

2.5.2 Test Participants. Training for test participants will consist of a pretest briefing covering test objectives, test approach and participant duties. The briefing will be followed by "hands on" instructions on the GTF equipment that will be utilized by the participants.

SECTION 3
DATA MANAGEMENT

3.1 DATA SOURCES. Data will be collected for analysis and evaluation to support the test objectives. Data will be collected from test participants by a combination of verbal response to test observers and written response to questionnaires.

3.2 DATA COLLECTION IN SUPPORT OF OBJECTIVES

3.2.1 Objective 1

3.2.1.1 MOP 1a. The data for this MOP will be the total time (measured in seconds) that the test participant uses in extracting (from the graphics display) the information required to respond to six tactical questions.

3.2.1.2 MOP 1b. The data for this MOP will be a written record of the test participants' responses to a series of six tactical questions.

3.2.2 Objective 2

3.2.2.1 MOP 2a. The data for this MOP will be a written record of the test participants' ordinal rankings of the four displays as a function of the degree of comfort they felt with the displays. For the purposes of this test the word "comfort" implies attributes such as "ease of use", "selectivity", "flexibility", and "adaptability" (see MCTSSA Doc. No. 24T001/U-TN-08, Handbook for TCO Test and Evaluation). Each participant will be tested on only two of the display types but will be familiarized with all four prior to collecting data for this MOP.

3.2.2.2 MOP 2b. The data for this MOP will be the recorded comments of each participant concerning his assessment of the compatibility of the various displays.

3.3 DATA REDUCTION. Data reduction will take place at the conclusion of each day of testing and will be recorded on the data reduction forms contained in Appendix B.

SECTION 4
DATA ANALYSIS

4.1 OBJECTIVE 1

4.1.1 Assumptions. It is assumed that the various measures are independent and normally distributed random variables, that all observations of a given MOP have the same variance and that the mean of each measure is a linear combination of certain unknown parameters.

4.1.2 Method of Analysis. Data analysis for Objective 1 will be based on a 2^2 factorial design (see Cochran and Cox, "Experimental Design", Wiley 1957). The factors and levels of factors are as specified in paragraph 1.4.

The null hypotheses for the test are that:

a. There is not a statistically significant difference between the large display and the small display as measured by the stated MOPs for Objective 1.

b. There is not a statistically significant difference between a display with and a display without a map background as measured by the stated MOPs for Objective 1.

c. There is not a statistically significant interaction effect between the two principal factors as measured by the MOPs for objective 1.

The analysis of variance (ANOVA) used to test the above hypotheses will be based on 48 observations (see Appendix C for a detailed mathematical methodology). Table 4-1 gives a breakdown of the 48 observations where the display types are as given in paragraph 1.4.3. This design allows for 12 observations of each display type.

Each of the 24 test participants will be randomly assigned to two display types such that four participants will utilize each of the six combinations of types (four types taken two at a time). Within these subgroups, the order in which display types are utilized will be equally divided. Since there will be a morning and afternoon session, an equal number of identical pairs of

displays will be tested in the AM and PM (see schedule in paragraph 2.2.1). Finally, the two scenarios will be used an equal number of times with each display type. This will be accomplished by having each test participant use Scenario I on his first iteration and Scenario II on his second iteration during the first week of the test and reversing the order during the second week of the test.

4.1.3 Interpretation of Results. After the ANOVAs for MOP 1a and MOP 1b have been performed a P-value for each null hypothesis will be calculated. A P-value is a statement of the probability that, if the null hypothesis is rejected, you are in fact rejecting the true case.

It is common that the null hypothesis is not rejected unless the P-value is less than a prescribed significance level (denoted). Typical significance levels are = .05 or =0.1.

4.2 OBJECTIVE 2

4.2.1 Method of Analysis

Although subjective in nature, MOP 2a will be assessed by constructing an interval scale based on the test participants' ordinal rankings of the four display types (Glenn F. Lindsay, "On Constructing Interval Scales from Ordinal Judgements", 1977, unpublished). As a check on the validity of the test participants' ordinal rankings, the Kendall coefficient of concordance will be used to test the hypothesis that the participants' judgments are unrelated/-inconsistent (see Siegel, "Nonparametric Statistics", McGraw-Hill, 1956). A detailed methodology for both procedures is given in Appendix C.

The subjective assessments submitted as MOP 2b will be quantitatively analyzed only to the extent that percentages of participants expressing a common observation will be identified. Otherwise a general summary of the assessments will be presented and commented on in the test report.

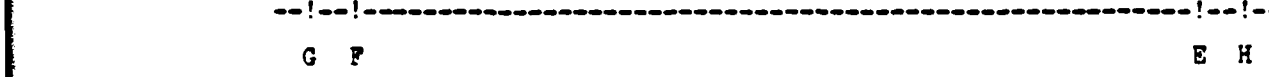
TABLE 4-1

BREAKDOWN OF TEST OBSERVATIONS

DISPLAY TYPE COMBINATIONS	NUMBER OF PARTICIPANTS	ORDER	NUMBER OF OBSERVATIONS
AB	4 < 2	A then B	4
	2	B then A	4 > 8
AC	4 < 2	A then C	4
	2	C then A	4 > 8
AD	4 < 2	A then D	4
	2	D then A	4 > 8
BC	4 < 2	B then C	4
	2	C then B	4 > 8
BD	4 < 2	B then D	4
	2	D then B	4 > 8
CD	4 < 2	C then D	4
	2	D then C	4 > 8
Totals	24		48

4.2.2 Interpretation of Results

The interpretation that can be made of an interval scale is best explained by an example. If four instances of some property being measured are denoted by the letters E, F, G and H (for this test the property being measured is "user compatibility" and the instances are the four display types) then an interval measurement of the degree of the property possessed by the instances might be presented by,



On such a scale, the base or zero point as well as the units are entirely arbitrary. It could be concluded that E and H possess more of the property than G and F, that there appears to be little difference between E and H as compared with the difference between E and F, etc. If the intervals between all instances were approximately equal then very little information is provided. In such a case, since the units are arbitrary, the intervals could represent large but equal differences or small but equal differences.

A high or significant Kendall coefficient of concordance may be interpreted as meaning that the test participants are applying essentially the same standard in ranking the display. If such is the case, confidence is added to the calculated interval scale.

APPENDIX A

SCENARIOS

A.1 INTRODUCTION. There are two scenarios, both of which involve a reinforced Marine infantry battalion conducting independent operations within a tactical area of responsibility (TAOR).

A.2 SCENARIO I

On D-day the Third Marine Amphibious Force (III MAF) conducted an amphibious assault on the beaches north of Oceanside, California. An enemy motorized rifle regiment is located north of Oceanside at the Santa Margarita Airfield. This airfield is a MAF objective. An enemy motorized rifle battalion is located in the city of Escondido, east of Oceanside. The MAF commander considers it essential that the enemy be denied the now deserted Palomar Airfield to the south of Oceanside. Accordingly, he specified that 1st Battalion, 4th Marines (reinforced with TOWS, engineers and sensor assets) be helicopter lifted to the Palomar Airfield on D-day with the mission to seize and defend the airfield, denying its use to the enemy until relieved by follow-on forces. The MAF commander designated a TAOR for this purpose and initially placed no restrictions upon fire or maneuver by the battalion commander outside the TAOR. Upon order, however, the battalion commander will be restricted to fire and maneuver within the TAOR as friendly forces approach the airfield.

It is now D+1, III MAF is ashore and the Santa Margarita Airfield has been taken. The 1st Battalion, 4th Marines is situated within its TAOR at the Palomar Airfield and has experienced no enemy contact up to now. The battalion commander has designated company areas of responsibility and instituted vigorous, continuous patrolling inside and outside of the TAOR.

A.3 SCENARIO II. The Third Marine Division is garrisoned in the city of Escondido, California. An enemy amphibious assault is probable. The assault may occur on the beaches north of the city of Oceanside, the beach south of the city of Carlsbad, or on the beach at Del Mar located south of the town of

Solana Beach. From its location at Escondido, the Third Division is in a good position to react to any of the possible landing sites. There are, however, two radio towers located northwest of the city of Vista which are of potentially critical political significance. In order to deny these towers to the enemy the division commander has assigned to the 1st Battalion, 4th Marines (reinforced with TOWS, engineers and sensor assets) a TAOR surrounding those towers, initially placing no restrictions upon the fire and maneuver by the battalion commander outside the TAOR. Upon order, the battalion may be restricted to fire and maneuver within the TOAR. This will occur if other friendly forces are deployed into that area. The battalion commander has designated company areas of responsibility and has instituted vigorous, continuous patrolling inside and outside of the TAOR. The enemy amphibious assault is now imminent.

APPENDIX B

DATA MANAGEMENT SYSTEM

B.1 INTRODUCTION. The purpose of the data management system is to organize the data for the test to ensure that all required data is collected and handled in an orderly manner.

B.2 DATA ORGANIZATION. A separate data file will be kept for each test participant; the participants will be designated as Test Participant #1 thru Test Participant #24. Each file will contain the following forms:

a.	Data File Cover Information	(Tab 1)
b.	Participant Profile Form	(Tab 2)
c.	MOP 1a Questionnaire for Scenario I	(Tab 3)
d.	MOP 1a Questionnaire for Scenario II	(Tab 4)
e.	MOP 1a Data Collection Form	(Tab 5)
f.	MOP 1b Questionnaire for Scenario I	(Tab 6)
g.	MOP 1b Questionnaire for Scenario II	(Tab 7)
h.	MOP 2a Instructions/Data Collection Form	(Tab 8)
i.	MOP 2b Questionnaire/Comment Sheet	(Tab 9)
j.	MOP 1b Score Sheet for Scenario I	(Tab 10)
k.	MOP 1b Score Sheet for Scenario II	(Tab 11)

B.3 DATA MANAGEMENT. Data Management for the test will consist of two major functions, data collection and data reduction.

B.3.1 Data Collection. At the beginning of each test day the data manager will fill out the cover information on each data file and deliver the appropriate data files to the work station test controllers. The work station test controllers will have the participant complete the Participant Profile Form and ensure that all data is collected in accordance with the following paragraphs.

B.3.1.1 MOP 1a. The work station test controller will ask the test participant to face away from the graphics display and then present him with the MOP 1a questionnaire corresponding to the test scenario being utilized. The test participant will be allowed to become familiar with the questions and to request clarification if necessary. After the participant indicates that he is ready to proceed, the work station test contoller will have the participant face the display and will start the timer. After the participant has recorded

his response to all questions the work station test controller will stop the timer. The work station test controller will then record the total elapsed time (to the nearest second) on the MOP 1a Data Collection Form and return all forms to the data file.

(NOTE: The test participant will be asked six questions which require information from the graphics display. Two questions will require use of overlay information only, two will require map information only and two will require information from both the map and the overlay.)

B.3.1.2 MOP 1b. The work station test controller will present the participant with the MOP 1b questionnaire corresponding to the scenario being utilized and ask him to provide a response to each of the six tactical questions. After the participant has completed the questionnaire the work station test controller will enter the information called for on the form and return it to the data file.

B.3.1.3 MOP 2a. After the participant has completed the test on the two displays assigned to him and has had an adequate amount of time to become familiar with the two displays not utilized, the work station test controller will explain the information required for MOP 2a. The test controller will then present the participant with four cards labeled A, B, C and D and have the participant arrange the cards in accordance with the instructions given. The test controller will then transfer the information to the MOP 2a Instruction/Data Collection Form and return all forms to the data file.

B.3.1.4 MOP 2b. At the conclusion of the test the work station test controller will have the participant complete the MOP 2b Questionnaire/Comment Sheet and then return it to the data file.

B.3.2 Data Reduction

B.3.2.1 Daily. After each participant has completed both test iterations, the work station test controller will transfer the participant's responses to the MOP 1b questionnaire to the appropriate MOP 1b score sheets, entering the total score in the space provided on the form. The work station test controller will then ensure that all other forms and questionnaires are complete, place all forms/questionnaires in the data file and return the data file to the data manager.

B.3.2.2 Data Consolidation. At the conclusion of the test period the data manager will consolidate all data utilizing the following forms:

a. MOP 1a Data Consolidation Form (Tab 12)

b. MOP 1b Data Consolidation Form (Tab 13)

c. MOP 2a Data Consolidation Form (Tab 14)

d. Data Consolidation Form for Kendall Coefficient (Tab 15)

TAB 1

DATA FILE COVER INFORMATION

Participant's Name _____
(last) (first) (m.i.)

Participant # _____ AM/PM Session _____

Iteration #1: Display Type _____ Scenario _____

Iteration #2: Display Type _____ Scenario _____

TAB 2

TEST PARTICIPANT PROFILE

NAME: _____ RANK: _____

YEARS OF SERVICE _____

MOSs	(1) _____	(2) _____	(3) _____
RELATED BILLET/ TIME SERVED	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___
	_____/___	_____/___	_____/___

AWS?
Yes / No

COMMAND & STAFF?
Yes / No

OTHER: _____

_____

_____

TAB 3

MOP 1a QUESTIONNAIRE
(SCENARIO I)

Participant # _____

1. Which patrol is closest to the water tower located approximately 700m west of the TAOR?

Answer:

2. Which company CP is farthest away from the battalion CP?

Answer:

3. What are the six digit grid coordinates of the water tower located west of the TAOR?

Answer:

4. Suppose TOWS are located at 751 668; their range is 3000m. Considering terrain, can those TOWS hit a target located at the intersection at 734 672?

Answer:

5. Which patrol is closest to the battalion OP?

Answer:

6. What is the distance between the battalion OP and the water tower located west of the TAOR?

Answer:

TAB 4

MOP 1a QUESTIONNAIRE
(SCENARIO II)

Participant # _____

1. What is the distance between the battalion OP and the spot south of the OP where the hard surfaced road crosses the railroad?

Answer:

2. Suppose TOWS are located at 738 767; their range is 3000m. Considering terrain, can those TOWS hit a target located at the intersection at 728 781?

Answer:

3. Which patrol is closest to the battalion OP?

Answer:

4. Which company CP is farthest away from the battalion CP?

Answer:

5. What is the six digit grid coordinate of the spot south of the battalion OP where the hard surfaced road crosses the railroad?

Answer:

6. Which company CP is farther from Guajome Lake?

Answer:

TAB 5

MOP 1a DATA COLLECTION FORM

Participant # _____

Scenario I:

_____ Min X 60 + _____ Sec = _____ Sec

Scenario II:

_____ Min X 60 + _____ Sec = _____ Sec

TAB 6

MCP 1b QUESTIONNAIRE
(SCENARIO I)

Participant # _____

1. What is the most likely spot for an LZ for an enemy helicopter borne assault on the Palomar Airfield?

a. VIC 715 674

b. VIC 740 655

c. VIC 760 655

d. VIC 756 649

2. What is the most likely enemy avenue of approach for a nonmechanized enemy attack from the south?

a. Along the axis 715 635 to 725 645 to the airfield.

b. Up the hard surfaced road from 750 632 to 749 640 to 752 650 to the airfield.

c. Up the draw from 756 640 to 756 646 to 754 650 to the airfield.

d. From 733 630 to 733 640 to the airfield.

3. The battalion commander is considering constituting a platoon-sized reserve. What would you recommend?

a. Take a platoon from A Co.

b. Take a platoon from B Co.

c. Take a platoon from C Co.

d. Do not constitute a platoon sized reserve.

4. Reliable intelligence reports a platoon of enemy tanks advancing towards the airfield from the east along Palomar Airport Road. Which is the best position for TOWS?

a. VIC 765 649

b. VIC 754 664

c. VIC 763 657

d. VIC 759 670

TAB 7

MOP 1b QUESTIONNAIRE
(SCENARIO II)

Participant # _____

1. What is the most likely spot for an LZ for an enemy helicopter borne assault on the radio towers?

a. VIC 745 772

b. VIC 717 778

c. VIC 733 777

d. VIC 752 753

2. What is the most likely avenue of approach for a nonmechanized enemy attack on the radio towers from the west?

a. Along Mission Ave. (Rte. 76) from 722 776 to 739 784, then down Santa Fe Ave. to 752 778 and on to the towers.

b. Along the railroad tracks from 737 740 to 752 750 then north to the towers.

c. From 716 766 to 728 762 to the towers.

d. From 720 740 to 732 750 to 740 760 to the towers.

3. The battalion commander is considering constituting a platoon-sized reserve. What would you recommend?

a. Taking a platoon form A Company.

b. Taking a platoon from B Company.

c. Taking a platoon from C Company.

d. Not constituting a platoon-sized reserve.

4. Reliable intelligence reports a platoon of enemy tanks advancing towards the TAOR from the west along Mission Avenue. Which is the best location for TOWS?

a. VIC 731 768

b. VIC 747 764

c. VIC 737 760

d. VIC 738 776

5. A battalion-sized enemy force is attacking from the east along the Palomar Airport Road axis. Two destroyers have been placed in direct support of 1st Battalion, 4th Marines. The battalion commander has designated the eastern boundary of the TAOR as the FEBA and deployed A Company and C Company in defensive positions along the FEBA with the same company boundary. He has designated B Company as the battalion reserve. Where would you recommend placing B Company?

a. Do not move them, i.e., keep them at VIC B Company CP.

b. VIC Battalion CP

c. VIC 751 644

d. VIC 752 654

6. Continuing the situation in question #5, where would you recommend relocating the 81mm mortar platoon?

a. Do not move them

b. VIC 752 656

c. VIC 722 669

d. VIC 740 650

TAB 8

MOP 2a INSTRUCTIONS/DATA COLLECTION FORM

Participant # _____

The participant will rank the four displays in the order that he feels that they possess the property of "user compatibility", i.e., in the order that he felt comfortable with the display. The participant is encouraged to rank all displays but he may omit one or more if he feels he can not judge that display. Ties are permitted (write ties on the same line). The participant should arrange the four cards marked A thru D until he is satisfied with the order.

Type A - Large Display with Map Background

Type B - Large Display without Map Background

Type C - Small Display with Map Background

Type D - Small Display without Map Background

Most Compatible _____

_____

_____

Least Compatible _____

TAB 9

MOP 2b QUESTIONNAIRE/COMMENT SHEET

Participant # _____

You are requested to comment on your assessment of the graphics displays you have seen today. Your comments should include what you liked/disliked about the displays, features you would have liked the displays to have, features you felt were superfluous or any other comment you feel is applicable. Use the back of the sheet if necessary.

TAB 10

MOP 1b SCORE SHEET
(SCENARIO I)

Participant # _____

1. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

2. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

3. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

4. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

5. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

6. Answer Points

   a. _____
   b. _____ Participant's Response _____
   c. _____
   d. _____

Total Points = _____ + _____ + _____ + _____ + _____ + _____ = _____

TAB 11

MOP 1b SCORE SHEET
(SCENARIO II)

Participant # _____

1. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

2. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

3. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

4. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

5. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

6. Answer Points

a. _____
b. _____
c. _____
d. _____

Participant's Response _____

Total Points = _____ + _____ + _____ + _____ + _____ + _____ = _____

TAB 12

MOP 1a DATA CONSOLIDATION FORM

Display Size	Map Background: Present — Type A		Map Background: Absent — Type B	
	Participant	Total Time	Participant	Total Time
Large	1		1	
	4		2	
	7		4	
	9		5	
	10		8	
	11		12	
	14		14	
	15		15	
	17		16	
	21		18	
	23		19	
	24		22	
	Type C		**Type D**	
	Participant	Total Time	Participant	Total Time
Small	2		3	
	3		6	
	5		8	
	6		10	
	7		11	
	9		12	
	13		13	
	16		18	
	17		20	
	19		21	
	20		22	
	23		24	

TAB 13

MOP 1b DATA CONSOLIDATION FORM

Display Size	Map Background: Present — Type A		Map Background: Absent — Type B	
	Participant	Total Score	Participant	Total Score
Large	1		1	
	4		2	
	7		4	
	9		5	
	10		8	
	11		12	
	14		14	
	15		15	
	17		16	
	21		18	
	23		19	
	24		22	
	Type C		Type D	
	Participant	Total Score	Participant	Total Score
Small	2		3	
	3		6	
	5		8	
	6		10	
	7		11	
	9		12	
	13		13	
	16		18	
	17		20	
	19		21	
	20		22	
	23		24	

TAB 14

MOP 2a DATA CONSOLIDATION FORM

f_{ij} Array

In each cell enter the number of test participants who ranked display type j above display type i

i \ j	A	B	C	D
A				
B				
C				
D				

TAB 15

DATA CONSOLIDATION FORM FOR KENDALL COEFFICIENT

f_{ij} Array

Participant	Display A	B	C	D
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
R_j =				

(4) Square each individual observation and sum

$$\frac{\left(\sum_{i=1}^{12} A_i^2\right) + \left(\sum_{i=1}^{12} B_i^2\right) + \left(\sum_{i=1}^{12} C_i^2\right) + \left(\sum_{i=1}^{12} D_i^2\right)}{48}$$

(5) Sum all observations, square this sum and divide by the total number of observations, i.e.,

$$\frac{\left(\sum_{i=1}^{12} A_i + \sum_{i=1}^{12} B_i + \sum_{i=1}^{12} C_i + \sum_{i=1}^{12} D_i\right)^2}{48}$$

(6) Row Sum of Squares = RSS = (1) - (5)

(7) Column Sum of Squares = CSS = (2) - (5)

(8) Interaction Sum of Sqrs = ISS = (3)-(5) - RSS - CSS

(9) Total Sum of Squares = TSS = (4) - (5)

(10) Residual/Error Sum of Sqrs = ESS = TSS - (5) + (5)

ANOVA TABLE

Source	Sum of Squares	DF	Mean Square	F Ratio
Size	RSS	1	MS_R = RSS	MS_R / MS_E
Map Bckgrnd	CSS	1	MS_C = CSS	MS_C / MS_E
Interaction	ISS	1	MS_I = ISS	MS_I / MS_E
Residual	ESS	44	MS_E = ESS/44	

C.2 OBJECTIVE 2

Methodology. The following methodology will be utilized to establish an interval scale from the ordinal judgments of the 24 test participants.

(1) The test participants' ordinal responses will be tallied into an f_{ij} array where f_{ij} is the number of participants who rank display j above display i, i.e.,

i \ j =	A	B	C	D
A	—	f_{AB}	f_{AC}	f_{AD}
B	f_{BA}	—	f_{BC}	f_{BD}
C	f_{CA}	f_{CB}	—	f_{CD}
D	f_{DA}	f_{DB}	f_{DC}	—

APPENDIX C
DETAILED ANALYSIS

C.1 OBJECTIVE 1

Factors

Display Size

Two levels - large, small

Map Background

Two levels - present, absent

Symbolic Representation of Data

Display Size	Map Background: Present	Map Background: Absent
Large	$A_1, A_2, \cdots A_{12}$	$B_1, B_2, \cdots B_{12}$
Small	$C_1, C_2, \cdots C_{12}$	$D_1, D_2, \cdots D_{12}$

Methodology

(1) Sum across rows, square these sums, add the squared sums, and divide by the number of observations in each row, i.e.,

$$\frac{\left(\sum_{i=1}^{12} A_i + \sum_{i=1}^{12} B_i\right)^2 + \left(\sum_{i=1}^{12} C_i + \sum_{i=1}^{12} D_i\right)^2}{24}$$

(2) Same as (1) for the columns, i.e.,

$$\frac{\left(\sum_{i=1}^{12} A_i + \sum_{i=1}^{12} C_i\right)^2 + \left(\sum_{i=1}^{12} B_i + \sum_{i=1}^{12} D_i\right)^2}{24}$$

(3) Same as (1) for each cell

$$\frac{\left(\sum_{i=1}^{12} A_i\right)^2 + \left(\sum_{i=1}^{12} B_i\right)^2 + \left(\sum_{i=1}^{12} C_i\right)^2 + \left(\sum_{i=1}^{12} D_i\right)^2}{12}$$

(2) A p_{ij} array will then be computed where,

$$p_{ij} = \frac{f_{ij}}{f_{ij} + f_{ji}}$$

On the diagonal of the p_{ij} array, we set $p_{ij} = .5$

(3) A z_{ij} array will then be computed where z_{ij} is the standard normal percentile corresponding to p_{ij}. The z_{ij} array will contain null elements corresponding to any $p_{ij} > .98$ or $p_{ij} < .02$.

(4) If the z_{ij} array has no null elements then the column averages will be used as scale values for the displays, i.e.,

$$s_j = \frac{\sum_{i=1}^{4} z_{ij}}{4}$$

(5) If the z_{ij} array has null elements then the least squares method will be utilized, i.e., compute column averages for those columns which are complete and use these averages as the value of the corresponding display. For incomplete columns write a set of linear equations of the form,

$$n_j s_j - \sum_{i \in \phi_j} s_i = \sum_{i \in \phi_j} z_{ij}$$

where ϕ_j denotes the set of n elements in column j of the z_{ij} array. Substituting for the scale values already determined, solve the set of simultaneous equations to obtain the remaining scale values.

Methodology for Calculating Kendall Coefficient of Concordance

The following methodology will be utilized to calculate a Kendall coefficient of concordance.

(1) The test participants' ordinal rankings of the various displays will be tallied into an r_{ij} array such that if the ith participant ranked the jth display as the "most compatible" then $r_{ij} = 1$. If the ith participant ranked the jth display as the "second most compatible" then $r_{ij} = 2$, etc.

In the event of ties the observations are each assigned the average of the ranks they would have been assigned had no ties occurred.

r_{ij} Array

Display	A	B	C	D
Participant				
1	r_{1A}	r_{1B}	r_{1C}	r_{1D}
2	r_{2A}	r_{2B}	r_{2C}	r_{2D}
.				
.				
.				
24	r_{24A}	r_{24B}	r_{24C}	r_{24D}

(2) Sum each column of the r_{ij} array, i.e.,

$$R_j = \sum_{i=1}^{24} r_{ij}$$

(3) Sum the Rs and divide by the number of displays, i.e.,

$$\bar{R} = \frac{\sum R_j}{4}$$

(4) Calculate the sum of squared deviations of each R from $\bar{R}$, i.e.,

$$s = \sum (R_j - \bar{R})^2$$

(5) Calculate the Kendall coefficient which is the ratio of s to the maximum possible sum of squared deviations, i.e.,

$$W = \frac{s}{2880}$$

(6) Convert W to a chi-square statistic with 3 degrees of freedom, i.e.,

$$\chi^2 (3) = 72W$$

(7) If the chi-square statistic is greater than or equal to 6.25 then the hypothesis that the participants' ratings are unrelated can be rejected at a significance level of $\alpha = .1$.